U. S. DEPARTMENT OF AGRICULTURE.

INDIAN CORN
(OR MAIZE)

IN THE

MANUFACTURE OF BEER.

BY

ROBERT WAHL, Ph. D.

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ANCIENT USE OF MALTED BARLEY.

Beer is one of the oldest among the so-called alcoholic beverages. It has been shown by recent research that long before the mythic Gambrinus of the Netherlands, who is popularly held to have been the inventor of the art of beer brewing, the ancient Egyptians were engaged in the preparation of this stimulating and nourishing article. They made beer from malted barley, which remains to-day the principal material employed by the brewing industry, which, during the last few decades, has grown to colossal dimensions.

BARLEY MALT REPLACED BY OTHER MATERIALS.

Besides barley malt other materials also found their way into the brewery. The practice of replacing barley malt by other materials, however, can not by any means be called an innovation. On the contrary, it has been in vogue from the earliest times in all countries that have produced beer or similar beverages. The products peculiar to the soil were used, more particularly in places where the cultivation of barley did not yield the desired results. Thus, in India and Japan a beverage called sake, similar to beer, is prepared from rice; in Russia kwas is made of rye; in Germany, the beer country par excellence, wheat malt and rice are used in addition to barley malt in the production of lager beer; in England large amounts of sugar are used in the production of ale and porter. In the United States of America the brewing industry has been turning, more and more, to the use of Indian corn, which is indigenous to the country, the practice having grown more particularly during the last few decades.

In view of this variety of materials used in the production of beer, in addition to hops and water, it becomes necessary to broaden the definition of the word "beer" and not confine it within the limits that have been placed upon its meaning by popular custom. If we bear in mind the fact that in Germany large amounts of rice and wheat are used, that still larger quantities of corn or maize are employed in the United States, and that enormous amounts of sugar are consumed in England and other countries, the definition of beer as "a beverage made of malt,

hops, and water," can not be accepted as correct, more particularly as corn, rice, and wheat are generally used in an unmalted condition. From the spread of such erroneous views the public receives altogether wrong ideas, and finally arrives at the conclusion that the use of any other material—as corn or rice—must be looked upon and disapproved of as an adulteration.

In the United States, for instance, last year there were used about 300,000,000 pounds of corn, together with barley malt, in the production of beer. The raising of this large quantity of grain, the cultivation of the farms, the work of harvesting the crop, the transportation of the grain to the markets, and its preparation for final use in the brewery give employment to thousands every year, and all this work, as well as the work of the brewer and the dealer, would have to be stamped, as it were, as illegitimate, if beer were to be defined as a beverage made of malt, hops, and water.

The question arises, What is the reason that the brewer uses other cereals besides barley malt? Why does he feel called upon to replace barley malt, in part, by wheat or corn or sugar; and why is it wrong to designate such a substitution as an adulteration? Does the partial use of other cereals offer other than pecuniary advantages?

VALUABLE PROPERTIES OF BEER.

In order to be able to treat this question intelligently it will be well to go into the science of the thing to some extent. The properties of beer that are particularly valued are: Fullness of body, a steady head of foam, brilliancy, stability, a certain aroma, and certain peculiarities of taste, be they bitter, sweet, sour, or otherwise. These properties depend upon the presence or absence of certain bodies in the beer. Thus, fullness depends upon the amount of dextrin, malto-dextrin, and albuminoids; the steadiness of the foam depends upon the same substances plus carbonic acid; the sweet taste depends upon the sugar; the bitter taste upon the hop resin, the acid taste upon the lactic acid; the aroma of hops upon the oil of the hops.

Both the brilliancy and stability of the beer suffer from the presence of organisms held in suspension, such as yeast and bacteria. Inasmuch as alcohol impedes the development of these organisms, it follows that the beer becomes more durable as the percentage of alcohol increases. The brilliancy and stability of the beer suffer, as a matter of fact, from the presence of any bodies held in suspension, that is, bodies that are present in an undissolved condition, as starch, secreted albuminoids, secreted hop resin, etc. The following fundamental principle may, therefore, be laid down: The properties of the beer are conditioned upon its composition.

The beer is made from the wort which the brewer obtains from the raw material by the processes of mashing and boiling. In the fermenting room the wort is pitched with a small amount of yeast, which is

completely removed subsequently. Hence, all the substances in the beer come either from the wort directly, as dextrin, mineral bodies, albuminoids, hop resin, hop oil, or they are developed by fermentation from substances contained in the wort, such as alcohol and carbonic acid from the sugar of the wort. The sugar being, under normal conditions, fermented almost completely and thus disassociated into alcohol and carbonic acid, it follows that the composition of a beer, and hence its properties, depend primarily upon the composition of the wort. The larger the amount of dextrin, malto-dextrin, and albuminoids in the wort the fuller will be the beer in taste and the steadier the foam; the more sugar there is in the wort, the more alcohol will appear in the beer, the greater will be its stability, etc.

Besides the composition of the wort, another factor which influences the character of the beer is the manner of conducting the fermentation. Thus, a top-fermented beer, as ale or porter, will possess an entirely different character from lager beer or bottom-fermented beers, even if the composition of the respective worts are the same, and this difference in character is to be traced, in the main, to the different modes of fermentation. In making lager beer fermentation is conducted at a low temperature; in making ale and porter, on the other hand, the temperature is comparatively high. A high temperature is much more propitious to the development of foreign ferments than a low temperature. Hence, whereas in making lager beers the low temperature acts as a natural preservative and a protection against infection, is it necessary if stable beers are to be prepared to look for another means in making ale and porter. This means consists in brewing in such a way that a larger amount of alcohol is developed during fermentation; that is, worts are made that contain more sugar, and therefore it is quite common in England, where top-fermentation beers are produced almost exclusively, to add sugar directly in the copper.

PRECAUTIONS NECESSARY TO INSURE STABILITY.

In making top-fermented beers a greater ratio of alcohol is, therefore, desirable, because it stops the development of the foreign ferments, whose growth is promoted by the higher temperature of fermentation and storage: it serves to make the beer more stable. However, as was pointed out before, the stability is influenced not only by foreign ferments, but also by secreted organic matter, such as albuminoids, starch, and hop resin. Among these, the albuminoids are dreaded most. They are responsible for that dull, unattractive appearance of the beer without any brilliancy, which is called "cloudy." This kind of turbidity is quite similar to that which is caused by foreign ferments; in this particular, also, that it appears to increase in the course of time and produces a sediment in bottle beers which becomes more voluminous as time goes on. Nor is there any means of removing the albuminoids from the beer. Filings, chips, and filter, which are the usual appli-

ances for clarifying, fail to accomplish the desired result. In bottle beers they are more unpleasantly prominent than even the foreign ferments. The ferments can be easily detected in beer, and a beer that is infected will not be used for bottling. It is more difficult, however, to discover the noxious albuminoids. A beer may rack off perfectly brilliant, and yet become turbid in the bottles after pasteurization.

The process of pasteurization is based upon the fact that all ferments are killed by being heated to a certain temperature. The bottles filled with beer are placed in water and this is gradually heated to about 140° F. (48° R.), maintaining this temperature for about 45 minutes. Ferments subjected to this treatment can not revive, therefore, even under the most favorable conditions, and no ferments can develop in a beer that has been properly pasteurized. Nevertheless, pasteurized beer is often found to be turbid and does not keep long. Upon examination it will then be found that the fault is with the albuminoids. In order to produce stable beers it therefore becomes necessary not only to secure a certain ratio of alcohol—more particularly in top-fermented beers, such as ale and porter—but it is necessary to avoid the formation of the noxious albuminoids, more particularly in producing bottle beers. The noxious albuminoids are either present in a finished condition in the material or they are produced during the mashing process. According to the materials used and the mashing method applied, larger or smaller amounts of these noxious albuminoids will be obtained in the wort, and our beers will be protected to a greater or less extent against turbidity from albuminoids.

THE BOTTLE-BEER INDUSTRY.

In no other country of the world has the production of bottle beer assumed such colossal dimensions as in the United States of America, nor are the requirements as to brilliancy and stability of the beer so high anywhere else; nor is there more accomplished in this direction in any other country. Bottle beers, which remain perfectly brilliant for many months, are produced here on a large scale. American bottle beers find markets not only in the entire Western Hemisphere, but also in those distant countries, like Australia, China, Japan, etc., where the production of beer is but little developed.

The success of American bottle beer, which has, within a short time, acquired a world-wide reputation, is due principally to one circumstance, to partial employment of raw cereals—that is, cereals that are not malted. Before the introduction of raw cereals it was a rare thing to find a stable bottle beer—that is, a beer which, if racked off into bottles and pasteurized, formed no sediment. It is thus seen that entirely apart from any pecuniary gain the use of raw cereals possesses material advantages. It is true, the same object could be accomplished by using sugar, as is done in England; but if such large quantities of sugar as would be necessary to obtain equal results were employed,

it would entail many disadvantages. Large quantities of sugar have an injurious effect upon the yeast by weakening it, and, furthermore, they will produce corresponding amounts of alcohol, which, although desirable for the sake of stability, as in the case of ale and porter, is not generally desired by the public that drinks lager beer, since in all countries a less intoxicating beverage is preferred, as a general thing, by the lager-beer drinkers. Furthermore, by choosing the proper methods of mashing it is possible where raw cereals are used to produce at will worts containing greater or smaller amounts of sugar, and hence beers of similar composition. The use of raw cereals, therefore, does not exclude the advantages which are afforded by sugar to the English breweries, for instance, while at the same time the evils mentioned are avoided.

MALT BEERS UNSTABLE.

The reason why stable beers can be produced only with difficulty from malt alone is to be found in the peculiar change in the character of the albuminoids, which is caused by the process of malting. During the malting the acrospire and the radicles feed upon the starch and the albuminoid bodies, which are deposited by nature in the barley corn for the germ. But neither the starch nor the albuminoids can be absorbed by the germ in their original form. This nourishment must first be transformed into more easily digestible combinations—it must be predigested, as it were.

This preliminary work is done by two so-called enzyma—chemical ferments—of which small quantities are present in the barley corn in its original state, and which appear in increasing quantity as the needs of the germ increase. One of these enzyma, the diastase, is there for the purpose of converting starch into maltose, a kind of sugar; the other one, called peptase, brings about the solubility of the albuminoids, which previously are in an insoluble condition, and from the crude insoluble albuminoids produces the peptones, which are easily digestible, maltose and the peptones, together with some mineral substances, making up the food of the germ. Besides the peptones, however, an intermediary product is formed, called protein, which is soluble in warm water or wort, but will be secreted when the fluid is cooled to lower temperature. Protein plays the following part in the manufacture of beer: During the preparation of the mash it is dissolved; when the wort is boiled it coagulates in part, while part remains in solution. On cooling, a part is secreted, which, while the beer is on storage, gradually settles to the bottom. Such parts as remain in suspension or are secreted in the finished beer give rise to albuminoid turbidity.

By rational malting, kiln-drying, and mashing the amount of protein and the noxious albuminoids in wort and beer can be limited and the stability of the beer be increased. The methods employed to this end embrace the following: The germs should be allowed to grow to suffi-

cient length on the malting floor; the malt should be dried carefully, finishing with a high temperature; the material should be doughed in—that is, the mash started at a low temperature. Where any of these rules are disregarded no great stability of the product can be expected, and even if all rules are strictly observed the result is often problematical and exposed to many vicissitudes.

In the United States these principal rules for the production of stable beers are being more and more recognized. Many brewers, however, do not appreciate the influence of a low initial temperature sufficiently, and they suffer by the limited stability of the beers or they are obliged to use extraordinary amounts of sugar in order to correct the mistake, which in turn is apt to cause fresh trouble, as weakening of the yeast, etc.

METHODS OF MASHING.

In this country as well as in England the so-called infusion method of mashing has been accepted quite generally, while in Germany, Austria, and other countries the so-called decoction method is practiced. But while low initial temperatures—100° to 120°—are generally observed in this country, Germany, and Austria-Hungary, the advantages of this rule do not appear to be appreciated in England. It is almost the universal custom in that country to mix the ground malt with water at a temperature over 145° F. At these high temperatures, however, the peptase loses its power of conversion, which is most intense, according to recent researches, between 100° and 135° F.—that is, in this interval of temperature it has the power to transform the injurious proteins into harmless peptones, which power it has lost at a temperature of 145°. Where the initial temperature in mashing, therefore, exceeds 145° there is no opportunity to convert the proteins which enter the wort in that form and later on create trouble for the brewer. The English brewer, however, prefers to use a high initial temperature because it saves time and labor and he is of the opinion that he utilizes the material more exhaustively.

It is true that in this way he reserves more water for sparging than with the low initial temperatures that are employed in the ordinary method practiced in the United States, and he tries to correct the bad influence of high initial temperature on the stability of his beer by using sugar, in which effort he is not successful, however, to the extent that his colleague attains in the United States by the use of raw cereals and a low initial temperature.

According to the English method—that is, by employing high initial temperatures—the brewer really accomplishes the opposite of what he desires. Not only does he fail to convert the injurious proteins, but the amount of sugar produced from the starch by the diastase turns out to be low. This creates a necessity to employ larger amounts of sugar in order to produce beers containing a high ratio of alcohol, which

is avoided by employing a low initial temperature of say 135°. In the latter case, the diastase will form large amounts of sugar in a short time and thus enable the brewer, even if malt only is used, to produce beers that fill all requirements as to the ratio of alcohol. All that is necessary to this end is to keep the mash at 135° F. long enough—for instance, an hour. The same result can be obtained where raw cereals are used. On the other hand, it is possible by raising the temperature in mashing more rapidly between 120° and 150°, to prevent the wort becoming very rich in sugar—which is undesirable for certain purposes—and the beer becoming too rich in alcohol. In this way beers are produced which are rich in dextrin, and without the danger of becoming turbid with albuminoids, provided part of the malt is replaced by raw cereals.

USE OF RAW CEREALS.

It appears from what has been said above that the use of raw cereals along with malt possesses certain important advantages which are other than pecuniary and can not be produced by any other system or in any other way. It further appears that the raw cereals contain no substances that do not occur in the barley or the malt, though possibly they may be found in other proportions. Moreover, the fact that a certain injurious substance, protein, which is always present in the malt, is always absent from the raw cereal, makes it not only justifiable but imperative from every point of view to use raw cereals in part wherever the advantages indicated can be obtained thereby.

Of course, there is no serious thought of using raw cereals to the entire exclusion of malt. Diastase and peptase, which have to convert starch into sugar and the albuminoids into peptones, are lacking in the raw cereals, or, at least, they are present only in minute quantities. It follows, therefore, that malt will always remain the basic and the principal material of beer, without which it would appear absolutely impossible to produce the refreshing beverage known as beer of such excellence as is required at the present day.

USE OF WHEAT, OATS, AND RICE.

The unmalted cereals which are to be considered in the manufacture of beer are wheat, oats, rice, and corn. The first three offer no special advantages. Barley and oats contain, in their husks, certain ill-tasting substances which have to be removed by steeping in water before these cereals can be used, which excludes them from competition with rice and corn in an unmalted condition. These ill-tasting substances are extracted in the production of malt by steeping the barley. Wheat, on the other hand, contains larger amounts of injurious proteins, and hence, whenever the production of bottle beers is considered, it does not enter into calculation at all.

It can not, therefore, be doubted that corn used moderately and with proper care is a perfectly legitimate article of brewing. Its dietetic value in human economy has repeatedly been pointed out by Dr. H. W. Wiley, chief chemist of the Department of Agriculture of the United States. In the Report on the Use of Maize (Indian corn) in Europe, he says:

As indicated by the above analyses, maize is fully equal in value as a food to any of the cereals, making up in its content of fat any deficiency which may be noticed in its nitrogenous matters and digestible carbohydrates. This conclusion, however, as to the food value of maize, does not rest alone upon the comparison of analytical data. The long years of use of this article by man and beast have shown its high character. Whether to be used as food for producing muscle for labor or as a means of fattening animals, it has been found to be of superior value to any of the other cereals produced in the United States. It feeds a large portion of the laboring men of the country, especially in the South. It is the almost universal food for fattening hogs, but in every function in which it has been used it has been found to bear out equally well the high place accorded to it from a study of its chemical composition.

This is a high tribute pronounced by a tried and respected scientist holding a high and responsible position. It ought to be sufficient to dispel every doubt regarding the virtues of this domestic product.

The chemical analyses upon which the opinion of Dr. Wiley is based are found in the tables given below:

TABLE 1.—*Chemical composition of leading cereals.*[1]

	Shelled oats.	Wheat.	Rye.	Barley.	Maize.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Water	6.93	10.27	8.67	6.53	10.04
Ash	2.15	1.84	2.09	2.89	1.52
Oil or fat	8.14	2.16	1.94	2.68	5.20
Digestible carbohydrates	67.09	71.98	74.52	72.77	70.69
Crude carbohydrates	1.38	1.80	1.46	3.80	2.09
Albuminoids	14.31	11.95	11.32	11.33	10.46

[1] Table taken from the Report on the Use of Maize, p. 19.

TABLE 2.—*Mean composition of cereals.*

[From Koenig compilation.]

	Moisture.	Crude protein.*	Crude fat.	Nitrogen free extract.†	Crude fiber.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Mean of 948 analyses of wheat from all countries	13.37	12.04	1.85	68.65	2.31	1.78
Mean composition of rice	12.58	6.73	0.88	78.48	0.51	0.82
Mean composition of rye	13.37	10.81	1.77	70.21	1.78	2.06
Mean composition of millet	11.79	10.51	4.26	68.16	2.48	2.80
Mean composition of barley	14.05	9.66	1.93	66.99	4.95	2.42
Mean composition of buckwheat	12.68	10.18	1.90	71.73	1.65	1.86
Mean composition of oats	12.11	10.66	4.99	58.37	10.58	3.29
Mean composition of maize from all countries	13.35	9.45	4.29	69.33	2.29	1.29

* Albuminoids. † Starch.

It will be seen from these tables that corn contains the same ingredients as barley, their ratio only being somewhat different. But there is a strikingly large amount of oil or fat, which is looked upon as a virtue by the farmer, but appears in a different light from the brewer's standpoint, as we shall see presently.

EFFECT OF THE CORN OIL ON THE QUALITY OF BEER.

The first successful attempts made in the United States to prepare bottle beer by the partial use of unmalted grain were made with rice, while corresponding experiments made with corn were complete failures. The beers made, in part, of rice had a good wholesome taste and great stability as bottle beers, whereas the taste of the corn beer was not all that could be desired, although it was not inferior in stability. Considerable time elapsed while an explanation of this difference was sought until, accidentally, perhaps, the grain which had been used as a whole as it left the cob was replaced by peeled and degerminated corn which had been known in the trade for a long time by the name of hominy. The taste of beer made in part of hominy was much improved.

The cause of the unpleasant taste of beer made by using corn in its natural condition will at once become apparent if a comparison is made between the composition of the grain of corn in its original condition on the one hand, and the composition of a product gained by careful peeling and degerminating or the composition of the grain of rice on the other hand, which respective data can be found in the following table compiled from analyses made in the laboratory of Wahl & Henius:

TABLE 3.—*Composition of crude and prepared grain.*

	Rice.	Prepared corn.	Crude corn.
	Per cent.	*Per cent.*	*Per cent.*
Water	10.60	12.00	12.50
Oil	.75	.64	4.90
Starch and other carbohydrates	77.89	77.59	65.67
Ash	.84	.40	1.62
Albuminoids	9.19	8.75	9.80
Cellulose (fiber)	.73	.62	3.51

RAW CORN AND PREPARED CORN.

Apart from certain neutral bodies, such as cellulose and mineral substances, raw corn is distinguished from prepared corn or rice by the large ratio of oil it contains. It is this oil that gives to the beer a rancid, coarse taste, which accounts for the fact that all attempts to replace barley malt by raw corn must fail.

The oil of the raw corn is concentrated in the germ. If the germ be completely removed the amount of oil in the product is, therefore, reduced to a minimum. All efforts to improve the product made since corn was introduced successfully in brewing are directed, in the main,

towards completely removing the germ from the mealy body. These experiments have been so signally successful that frequently products of corn in which the ratio of oil is less than even that of rice are put upon the market and hence products of this kind are to be preferred to an average quality of rice for purposes of beer making. A well-degerminated corn, therefore, must at least be held to be of equal value to rice in every particular.

Together with the germ the hull is removed with the result that the prepared corn shows less cellulose and more starch than raw corn.

Brewers' corn is prepared from raw corn by machines of very ingenious construction. The raw corn is cut up by a number of revolving sharp knives, the germ and hull being detached and separated from the hominy by a current of air. The hominy is ground and the flour is sorted into different degrees of fineness by sieves and dried in kilns.

The coarser the flour the better the goods, as a general thing. The pieces of the germs remaining in the hominy, being crushed fine in the grinding, thus get into the finer grades of flour, which by this means come to contain more oil than the coarser ones, which are commonly called "grits." While the grits are preferred for brewing, the finer ground products serve for food, and germs mixed with the hulls are a valued article of trade as cattle feed.

The following table shows the composition of the various products obtained from raw corn by crushing, grinding, sorting, and drying, according to the average figures resulting from analyses made in the laboratory of Wahl & Henius:

TABLE 4.—*Composition of products obtained from raw corn.*

	Flint corn.	Coarse grits.	Fine grits.	Meal.	Flour.	Husks and germs.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Water	14.20	12.00	12.50	12.50	12.50	14.50
Oil	4.81	.75	1.04	1.92	3.04	9.19
Starch and other carbohydrates	66.19	78.42	77.11	75.79	72.55	53.92
Albuminoids	9.54	7.60	7.40	7.50	8.32	9.27
Ash	1.50	.45	.63	.73	.94	3.00
Raw fiber	3.70	.78	1.32	1.56	2.65	10.12

The kind of corn used for the production of brewers' grits is the species known as white flint corn, which at the present time is cultivated on a large scale in several States of the Union, more particularly in Indiana, Illinois, and Nebraska, exclusively for such mills as make a specialty of brewers' grits.

Products from flint corn have a better appearance and contain less oil than those made of red or mixed corn. The above table shows that the quality of the product improves as the ratio of oil decreases. The greater the amount of oil, the greater also the amount of neutral bodies, such as cellulose and albuminoids, and the less the amount of the valu-

able substances—that is, starch. The percentage of oil can thus be looked upon as an indicator of the value of a corn product for brewers, more particularly if the percentage of water, which is independent of the oil, be known.

In the laboratory of Wahl & Henius the corn products of the trade are measured by the percentages of oil and water which they contain. It is thus a very simple matter to speedily determine the value of such products analytically. This is an advantage that should not be underrated, as it is impossible to judge the goods with certainty from their appearance only.

ANALYSES OF CORN PRODUCTS.

Among more than 5,000 samples sent for analysis to the laboratory of Wahl & Henius during the year ended June 30, 1893, there were 577 samples of corn products which it will be interesting to group in tabular form with reference to the percentages of oil and the mode of judging them.

There were among these samples—

10 containing 0.2 to 0.5 per cent of oils, quality excellent.
102 containing 0.5 to 1.0 per cent of oils, quality very good.
142 containing 1.0 to 1.5 per cent of oils, quality good.
114 containing 1.5 to 2.0 per cent of oils, quality medium.
153 containing 2.0 to 3.0 per cent of oils, quality poor.
46 containing 3.0 to 4.0 per cent of oils, quality very poor.
10 containing over 4.0 per cent of oils, quality raw corn.

Such corn products as were shown by chemical analysis to contain over 2 per cent of oil were pronounced unfit for brewing purposes. Among the samples sent in, it thus appears that 209, or 36.2 per cent, were condemned as unfit for use. This is sufficient reason to again admonish the brewer to be careful in buying such products. Of course the limits of the permissible percentage of oil may be varied within very narrow lines with reference to the percentage of corn used in the brewing. The smaller this percentage is, the higher the limit of oil may be carried. Where 40 per cent of corn was used, it was admissible to let the percentage of oil run to 2 per cent; where 20 per cent of corn was used, even to 2.5 per cent. But a product containing over 2.5 per cent of oil should not be used for brewing under any circumstances.

The average, maximum, and minimum figures for water and oil in the 577 samples were:

	Average.	Maximum.	Minimum.
	Per cent.	*Per cent.*	*Per cent.*
Water	11.27	16.00	7.50
Oil	1.73	5.45	.20

The permissible limit for water in the corn product has for a long time been placed at 13 per cent. The less water, the greater the ratio

of starch and the better will the product keep if stored for any length of time. Whenever the percentage of water exceeds 13 per cent Wahl & Henius recommend that a suitable deduction be made from the market price of the goods. In the case of goods intended for export across the ocean, I would recommend that they be dried until the water is diminished to 10 per cent.

PREPARATION OF CORN PRODUCTS FOR MASH TUB.

Corn products, such as brewers' grits and brewers' meal, can not be used in the mash tub directly with malt; they must be prepared and opened up.

In a state of fine distribution, as in starch flour or in the condition in which it is placed by the malting process, starch is readily converted by the action of diastase into dextrin and sugar at comparatively low temperatures—120° to 167° F. This conversion is preceded by the liquefaction of the starch. The higher the temperature of the water, the more rapidly will the starch be liquefied. At a temperature over 167° F. starch is liquefied more rapidly than at lower temperatures. A malt mash, however, must not be heated above 167° F., because at higher temperatures the diastase is weakened, if not killed, and no more starch can be converted, thus causing losses. Moreover, an imperfect conversion of starch easily leads to turbidity. In brewers' grits and meal, however, the starch is not finely divided and porous, as are the mealy parts of the malt, but the individual granules of starch are close together, forming a coherent, hard, glassy or horn-like substance, which will resist liquefaction much more successfully, and at temperatures below 167° F. will liquefy only very slowly, and hence be very slowly converted by the diastase of malt. It follows that if brewers' grits or meal is added directly in the mash tub, together with or after the malt, the mashing process would last a very long time, or a greater loss of material would result. The coarser the corn product, the worse these evils become. If it is desired, therefore, to use corn products in the mash tub, they must be so prepared that the starch will easily dissolve below 167° F., like the starch of malt, or else it will be necessary to open up the corn in a separate tub by employing higher temperatures and to delay mixing the mash of the raw cereal with the malt mash until this is done.

If the brewer has not a separate tub at his disposal in which he can prepare the corn by using higher temperatures, he can get goods prepared for this purpose and add them directly in the mash tub. These goods are known in the trade in this country under various names, as cerealine flakes, frumentum, or maizeline. They are prepared from well-degerminated corn by steaming, rolling, and drying. They consist, for the most part, of thin flakes of starch, which dissolve in the mash tub as readily as the malt itself, and may be doughed in together with the malt. As a general thing the crushed malt is mixed with water in the mash tub, and the steamed corn product follows immediately.

This method is applicable both to the infusion mashes, which are customary in America and England, and for decoction beer, as it is made in Germany. The yield from goods prepared in this way is about equal to that which is obtained from brewers' grits or meal if treated by itself in a separate tub. It is possible, also, to prepare grits or meal by simply grinding fine and then scattering into the mash tub. But this method is not to be recommended.

The most general method consists in opening up the corn products in a separate tub at a higher temperature. The tub is a simple cylindrical vessel made of strong sheet iron, and has a conical projection at the bottom. In the center a stirring apparatus turns on a perpendicular axis. At the bottom, where the cone and the walls of the kettle join, are the inlets of a number of steam pipes, which conduct steam direct to the tub, or a steam coil, with indirect steam, attached below in the interior of the tub. A clean wooden tub might be fitted up for an experiment, if need be. In Germany the decoction pan could be used to great advantage for opening up the corn. The practical carrying out of the process is subject to changes, according to individual opinions.

The following process will give good results under all circumstances: Run water of about 100° F. (30° R.) into the corn tub. (Cold water may also be used and then heated in the tub to the same temperature.) Throw in some ground malt, about one-fifth or one-third of the weight of the corn to be used. Then follows the corn. The mash is kept at a temperature of 100° F. (30° R.) for about thirty minutes, while the stirrer remains in operation; then heat rapidly to 154° F. (54° R.), keeping this temperature for about thirty minutes; rapidly heat to boiling and boil for one hour or one hour and a half, according to the fineness of the material—the coarser the corn product the longer it will be necessary to boil; then run the corn mash into the mash tub, where the malt has previously been doughed in at a higher or lower temperature, according to the character of the beer to be produced. In the United States it is advisable to dough in malt in the mash tub at 100° F. (30° R.) The mash tub is generally provided with pipes for direct steam. The mash should be kept at 100° F. (30° R.) for thirty minutes; then heat by steam to 122° to 133° F. (42–45° R.) and in fifteen minutes add the corn mash, allowing the temperature to reach 154° F. (54° R.) in fifteen minutes. At this point the temperature is kept for ten minutes, reaching a final temperature of 162° F. (58° R.) at the expiration of that time. In England it would be practicable to introduce water of 146° F. (50° R.) into the mash tub, obtaining a temperature of about 133° F. (45° R.) after mixing in the malt. Keep at this temperature for thirty minutes, and then run in the corn mash until the temperature of 154° F. (54° R.) is reached. This temperature is maintained for fifteen minutes, when the mash is immediately heated to a final temperature of 162° F. (58° R.).

The object in raising the temperature from 133° F. to 154° F. (45–57° R.) in thirty minutes is to give more time for conversion to sugar. For the same reason the temperature of 133° F. (45° R.) is maintained for half an hour. The best way of preparing the corn mash is the one customary in the United States. Accordingly as the temperature of the malt mash is kept at 133° F. (45° R.) for a longer or shorter time, and accordingly as the temperature is raised to 162° F. (58° R.), slowly or quickly worts will be obtained which contain more or less sugar, hence beers containing more or less alcohol. In preparing decoction beers, such as are made in Germany and Austria-Hungary, it would be practicable, as was observed above, to use the mashing pan (which is found in almost every brewery) for preparing the corn. In this case it is advisable to add a portion of the corn in the wort pan and boil it with the first thick mash, another portion to the second decoction, and another portion to the "Lauter" mash. Inasmuch as it is not optional what length of time to boil these mashes, it would here be necessary to use a more finely ground product, but it would also be practicable to add all the corn to the Lauter mash, boiling it for an hour and then joining it with the principal mash.

Another method to be recommended for decoction beers is the following: Dough in the malt with water of the ordinary temperature, stop the mash machine, draw a cold Lauter mash and keep it stored for future use. Hot water is added to the mash in the mash tub until the temperature of 122° to 127° F. (40–42° R.) has been reached. The stirrer being kept in operation, a warm Lauter mash is drawn, which is run into the mashing pan, where the corn is also run in; heat up to 154° F. (54° R.), keep here for thirty minutes, raise to boiling heat, and boil for an hour, then run off the corn mash into the mash tub. At the temperature of 154° F. (54° R.) the cold solution is run in and the mash is heated to a final temperature of 162° F. (58° R.)

INFLUENCE OF MASHING METHOD.

The influence of the mashing method upon the composition of the beer has for a long time been the object of thorough investigation in the laboratory of Wahl & Henius. I refer to the Fourth Annual Report of this institution, which appeared in 1891, from which I quote the following:

In America, as is well known, the mash is prepared according to the infusion method, the various mashing methods differing principally in regard to the initial temperature employed and the length of time allowed for mashing upwards.

To what extent the character of a beer is influenced by changing the initial temperature and the time for mashing becomes apparent in giving the analyses of the various beers consideration, and it can be claimed that a beer of definite composition within certain limits, and as far as alcohol and extract are concerned, can be made dependent upon the method employed for mashing.

From the large number of analyses made we will produce three of beers which we consider as characteristic. All of these were brewed with 70 per cent malt and 30 per cent of raw cereals.

No. 1 was doughed in at 45° R. (133° F.) and inside of thirty minutes mashed up to 60° R. (167° F.) with the boiled raw cereal mash.

No. 2 was doughed in at 28° R. (95° F.) and mashed up to 48° R. (140° F.) with water in thirty minutes. The mash was then allowed to stand a half hour, and subsequently mashed up to 60° R. (167° F.) in thirty minutes with the boiled raw cereal mash.

No. 3 was doughed in at 40° R. (122° F.) and mashed up to 60° R. (167° F.) in forty-five minutes with the boiled raw cereal mash.

	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
Balling	6.96	2.17	4.70
Alcohol by weight	3.20	5.01	3.80
Extract	7.95	4.45	6.40
Maltose	1.94	1.06	2.00
Albuminoids	.36	.71	.49
Lactic acid	.07	.09	.07
Degree of fermentation	49.00	70.00	53.00
Original gravity	14.12	14.23	13.80
Maltose to nonmaltose	100.73	100.31	100.47

The above analyses show beers No. 1 and No. 2 to be of entirely different character as far as extract and alcohol are concerned. No. 1 is a beer containing little alcohol and much extract, whereas No. 2 contains little extract and much alcohol.

According to the analyses one would be inclined to think that beers of a composition corresponding to that of No. 1 above would be very desirable, and that they would be very full-bodied. This is, however, not the case, but, on the contrary, beers having a composition analogous to No. 1 above are generally accompanied by a complaint regarding their empty taste, and this is very seldom heard in connection with a beer of the composition of No. 2. This fact seems to stand in direct contradiction with our present knowledge in this connection, as it is generally supposed that a beer rich in "extract" is, respectively, also full-bodied.

We therefore repeatedly call attention to this point, as the practice of preparing beer containing little alcohol and much "extract" may lead too far, and at the expense of other very important points. The albuminoids, which we think the most important factor in relation to the body of a beer, must not be left out of consideration. Invariably we find that beers prepared similarly to the method cited in connection with beer No. 1 contain few, and such as are prepared similarly to beer No. 2 proportionately many, albuminoids.

COMPARISON OF AMERICAN WITH FOREIGN BEERS.

It will be interesting to compare the composition of English beers and decoction beers with that of peculiarly American beers.

TABLE 5.—*Composition of German and English beers.*

[From Koenig's compilation.]

	Bürgerliches Bräuhaus Pilsen (275).	Waldschlössehen Kiel (189).	Schwichater, Vienna (252).	Dark lager beer (209).	Schönbucker, Herlet-Königsberg (183).	Marienborn, near Siegen (155).	Stock Company Königstadt, Berlin (pale) (162).	Hemelingen, near Bremen (171).	Hofbräu, Munich (9).	Löwenbräu (14).
	Sp. gr. 1.0130	*Sp. gr.*	*Sp. gr.* 1.0163	*Sp. gr.* 1.0252	*Sp. gr.* 1.0265	*Sp. gr.* 1.0113	*Sp. gr.* 1.0157	*Sp. gr.* 1.0121	*Sp. gr.* 1.0141	*Sp gr.* 1.0181
Balling*	3.25	....	....	....	....	....	....	....	....	....
Alcohol	3.32	3.84	3.72	3.17	4.01	4.13	4.19	3.89	3.88	3.48
Extract	5.08	6.50	5.60	7.73	6.75	4.93	5.28	4.93	4.93	6.20
Albumen	....	....	0.31	0.56	0.78	0.88	0.37	0.92	0.43	....
Sugar	....	....	....	2.97	1.43	....	1.38	....	....	1.17
Lactic acid	0.12	....	....	0.053	....	0.184	0.141	0.137	....	....
Ash	0.18	....	0.18	0.22	0.39	0.18	0.191	0.20	0.23	....
Original density of wort*	11.52	13.98	12.84	13.87	14.57	12.99	13.46	12.51	12.49	12.96
Degree of attenuation*	55.90	53.80	56.30	44.27	53.67	62.05	60.77	60.58	60.53	52.16

	Münchener Kindl (32).	Hacker, Munich (24).	Erlanger export (48).	Bass's ale, Burton (13).	Allsop's ale (14).	India pale ale (18).	Dublin porter (4).	Single Dublin porter (12).	Guinness' stout (40).
	Sp. gr. 1.0151	*Sp. gr.* 1.0177	*Sp. gr.* 1.0170	*Sp. gr.* 1.0138	*Sp. gr.* 1.0144	*Sp. gr.* 1.0140	*Sp. gr.*	*Sp. rg.* 1.0243	*Sp. gr.* 1.0681
Alcohol	4.48	3.71	5.07	6.34	6.30	5.72	9.04	4.92	5.66
Extract	5.97	6.12	6.17	6.87	4.37	5.90	8.49	5.34	7.42
Albumen	1.02	0.96	1.03	0.48	0.45	....	0.79	0.43	....
Sugar	....	....	....	....	....	0.66	0.34	....	1.51
Lactic acid	0.203	....	0.142	....	....	....	0.35	....	0.523
Ash	0.207	....	0.23	....	....	....	0.42	....	....
Original density of wort*	14.73	13.34	16.11	19.35	16.77	17.64	26.37	14.98	18.54
Degree of attenuation*	59.47	54.12	61.70	64.50	73.94	65.58	67.80	64.35	59.97

* Calculated.

As in the American beers, so in the German and English beers, we are met by the greatest variety of composition. Hence we do not find any uniformity of character in the foreign beers any more than in American beers. The principal ingredients which determine the character of a beer appear in varying quantities. Thus the albumen of the German beers enumerated above varies from 0.31 to 1 per cent, alcohol from 3.82 to 4.48, extract from 4.43 to 7.73, etc. In the English beers, it is true, we see on the whole a large percentage of alcohol coupled with a comparatively low amount of extract, which is also seen in No. 2, Table 1, of our American beers. American beers Nos. 1 and 3, on the other hand, approach more nearly to the German beers. By a proper selection of the method of mashing, therefore, we are enabled to produce beers whose composition agrees with the English beers on the one hand and with the German beers on the other hand. There is, therefore, no plausible reason why

corn should not be used in England and Germany as well as in the United States. Moreover, corn is cheaper, pound for pound, than either barley malt, sugar, or rice, while it yields as much extract as rice or grape sugar and much more than barley malt.

The following comparative statements will show the pecuniary advantages which will accrue to the brewer from the use of corn:

If 100 pounds of corn yield in practical brewing 80 pounds of extract,
If 100 pounds of rice yield in practical brewing 80 pounds of extract,
If 100 pounds of barley malt yield in practical brewing 65 pounds of extract,
If 100 pounds of grape sugar or glucose yield in practical brewing 80 pounds of extract,
If 100 pounds of cane sugar yield in practical brewing 100 pounds of extract;

It follows that—

100 pounds of corn are equal in value to 100 pounds of rice;
100 pounds of corn are equal in value to 123 pounds of barley malt;
100 pounds of corn are equal in value to 100 pounds of grape sugar;
100 pounds of corn are equal in value to 80 pounds pure cane sugar.

Our domestic corn thus offers special advantages when compared with other materials, and it is time to take from under the bushel the light which science and practice have united in kindling, and let it shine before all the world.